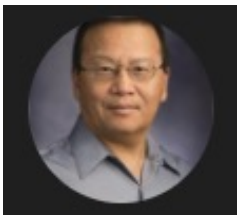




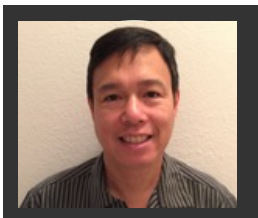
Ground Stations as a Service (GSaaS) for Near Real-time Direct Broadcast Earth Science Satellite Data



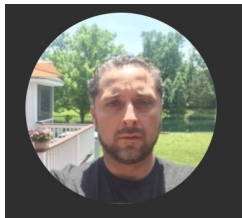
Louis Nguyen
NASA Langley Research Center
Hampton, VA

ESTF-2021 June 10, 2021

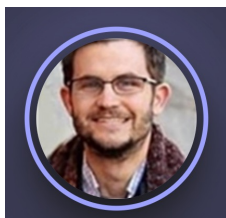
SatCORPS Team Members at NASA Langley



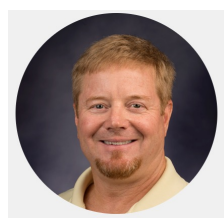
Thad Chee



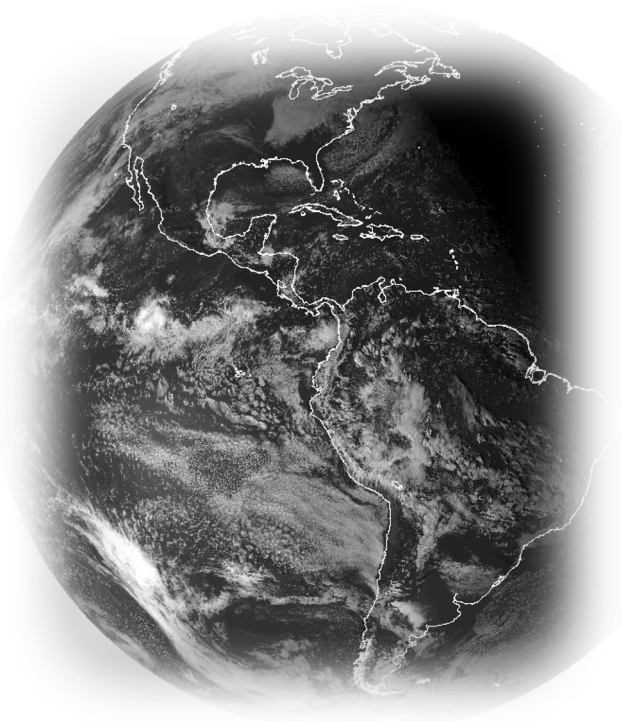
Andrei Vakhnin



Jason Barnett



William Smith, Jr





Presentation Contents

- Background / Objectives
- Amazon Ground Station as a Service
- GSON System Architecture Framework
- Direct Broadcast Products
- GSON Service Layer API
- Summary and Future Plans

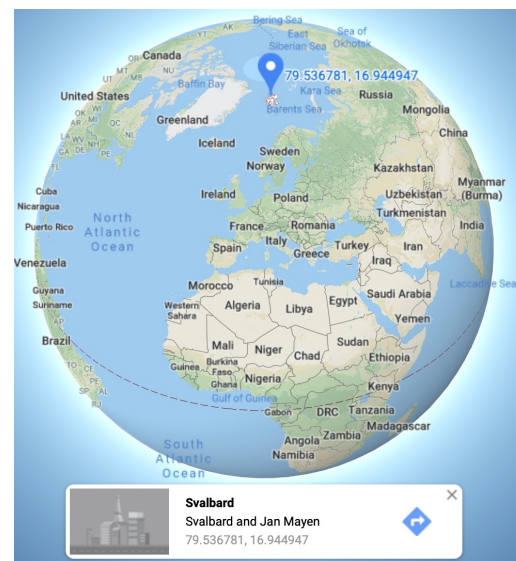


Background

This project will develop a system to address the “**Data Latency**” issues associated with acquiring LEO satellite data and demonstrate how AWS Ground Station as a Service (GSaaS) network can be used to receive near real-time Direct Broadcast (DB) data. With connectivity to Amazon’s computing infrastructure (network, compute, and storage), this cloud-based framework, along with GSaaS, will enable low latency DB data from EOS to be received, processed, and delivered to end users and near real-time applications.

Motivation:

- Data latency issue (3 more hours) poses a significant impact on data product optimal use due to delay in use of single receiving station
- Real-time observation from LEO satellites are needed to better support weather diagnoses and forecasting, disaster management, airborne science research, and other Earth Science applications
- Provide low latency DB data on the Amazon Cloud for use by NRT applications



Svalbard receiving station in Norway acquires NASA EOS data and sends it to Data Center at GSFC with data latency.



Background

- Many NRT applications requires low latency LEO data $<$ than 1.5-3 hrs

- **What is the Current Solution?**

- Requires local DB ground site to receive low latency data
- Expensive to operate and maintain
- Access to local DB data is private, limited and/or restricted
- No efficient platform for data sharing low latency DB data

DB Sites with X-band and Direct Readout



- **Alternative Solution:**

- Use Amazon Ground Stations as a Service (GSaaS)



Objectives

Project is funded by NASA Advanced Information Systems Technology (AIST-QRS-20) for support of New Observing Strategies Testbed (NOS-T) Concept

Our Goals:

- Build Ground Station Observation Network (GSON) framework for acquiring NRT DB data using Amazon GSaaS; demonstrate concept
- Implement workflow for processing products and triggers (events) from DB data (MODIS/VIIRS) for NOS-T nodes within the GSON framework
- Extend GSON capabilities to include micro services and API for use by Apps/Users/NOS Testbed nodes to schedule, coordinate, reserve, received, process, and deliver low latency DB satellite data and products
- Achieve data and product generation with latency down 20-25 minutes; improve NASA Earth Science applications ability to deliver lower latency data and products to end users
- Provide capabilities to acquire NRT DB data from AQUA, TERRA, NPP, JPSS-1
- Enable NASA Langley SatCORPS to deliver NRT cloud products from LEO



Presentation Contents

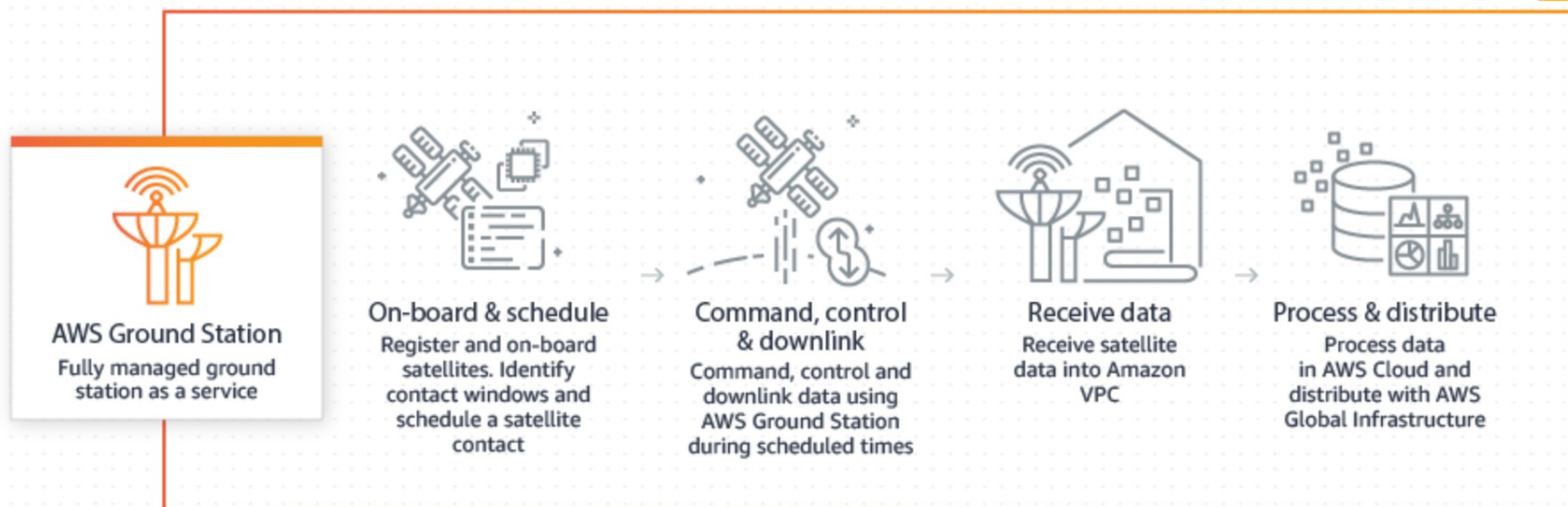
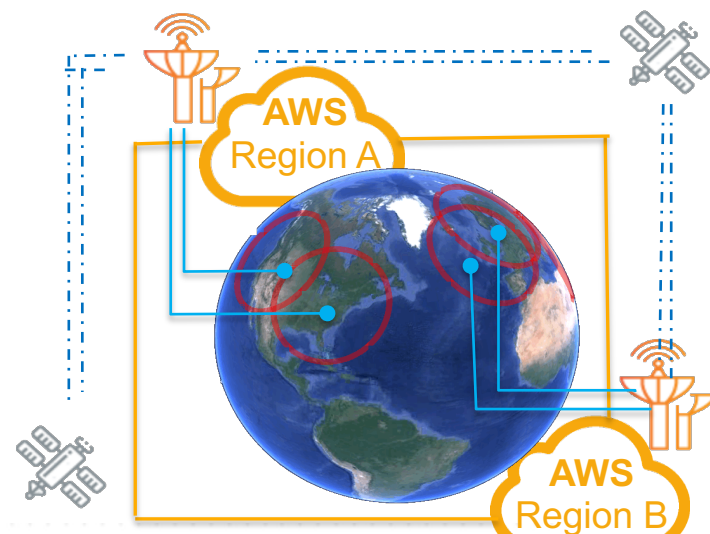
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Amazon Ground Station as a Service (GSaaS)

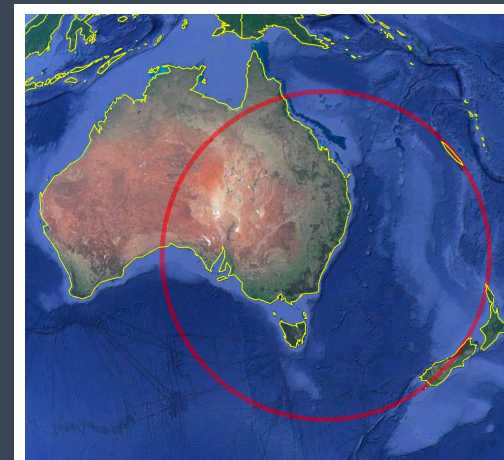
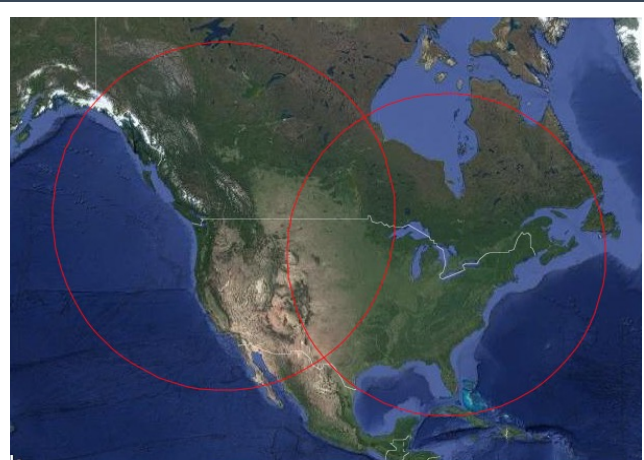
How GSaaS works

- Provides global network of ground stations
- On-boarding and Scheduling
- Downlink direct broadcast data
- Allows uplink for command and control
- DB data received by VPC instance
- Data delivered to S3 for processing and distribution





AWS Ground Station Regional Coverage



- AWS currently have 6 operational GS: Ohio, Oregon, Bahrain, Stockholm, Dublin, Sydney
 - GS network expected to expand to over 12 AWS Regions worldwide
- DB can be received within the ~2000km range of each GS; Data -> S3 in real-time
 - Capable of receiving X- and S- Band frequencies from LEO and MEO
- Pay as you go service for use of antenna; charged by the minute
 - reserved cost~\$3 per min and more for on-demand
- GSON system provides end-to-end service
 - Coordinate, schedule, receive, process, and deliver low latency data



Amazon Ground Station Console

Reserving Satellite Contact using Console GUI

✓ **Reservation submitted**
Your contact reservation has been submitted. You can view its status within the Contact management table.

AWS Ground Station > Contacts

Contacts

Contact management (23)

Manage contacts using the table below.

Ground station

All ground stations

Satellite catalog number

27424

Status

All

Mission profile

27424 Aqua

Start date and time (UTC +00:00)

2020/03/12

17:08

End date and time (UTC +00:00)

2020/03/17

17:08

Cancel contact

272

Reserve contact

You are about to reserve a contact.

Reservation information

Satellite catalog number

27424

Ground station

Ohio 1

Start time

2020-03-12T18:45:38.000Z

End time

2020-03-12T18:57:23.000Z

Max elevation (degrees)

70.66

Mission profile

27424 Aqua (us-east-2)

Tags- optional

Add optional tags to the contact reservation.

Key

Value

Cancel

Reserve

	Catalog number	Ground station	Start time (AOS) ▲	End time (LOS)	Maximum elevation (deg.)	Region	Status
<input type="radio"/>	27424	Ohio 1	2020-03-12T17:10:25.000Z	2020-03-12T17:15:06.000Z	12.98	us-east-2	COMPLETE D
<input checked="" type="radio"/>	27424	Ohio 1	2020-03-12T18:45:38.000Z	2020-03-12T18:57:23.000Z	70.66	us-east-2	SCHEDULI NG
<input type="radio"/>	27424	Ohio 1	2020-03-12T20:27:47.000Z	2020-03-12T20:31:59.000Z	5.56	us-east-2	AVAILABLE



Presentation Contents

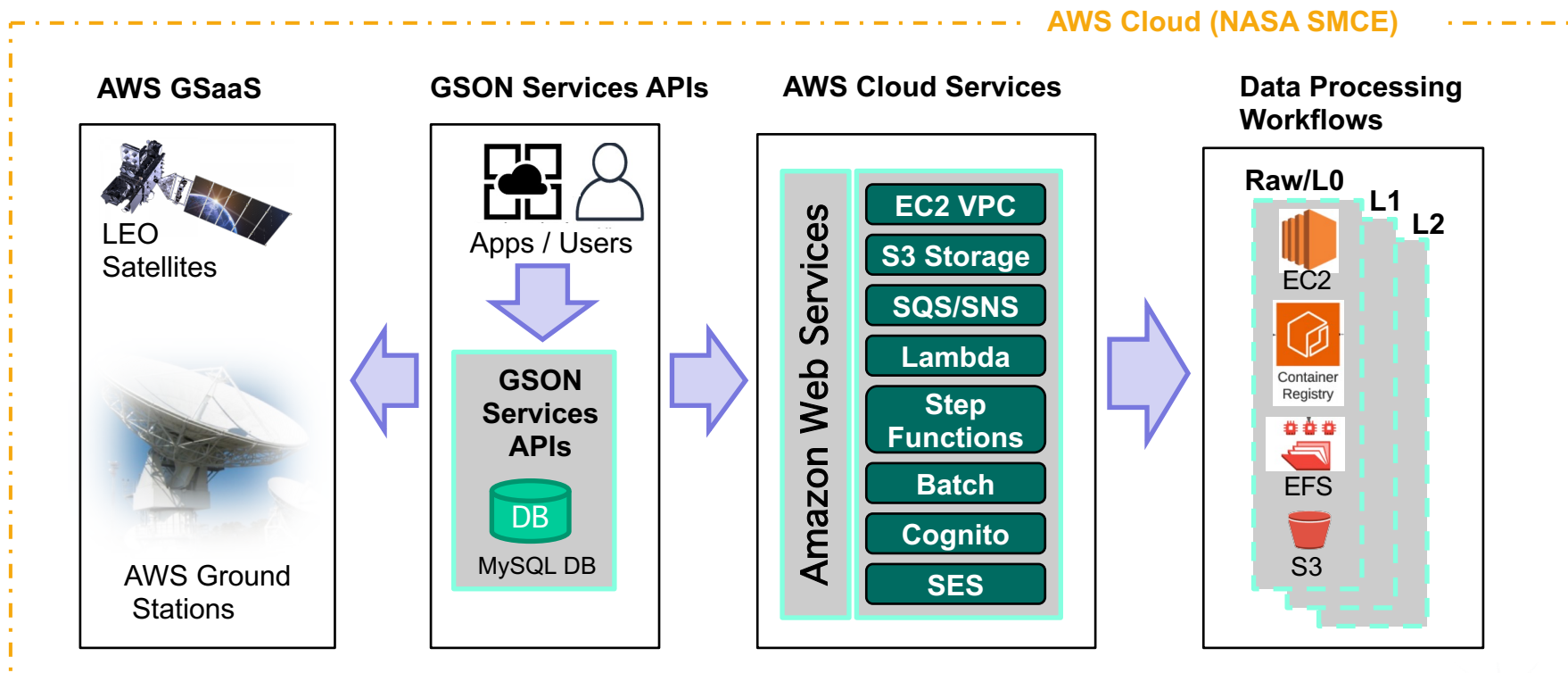
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GSON System Architecture

GSON Framework Components

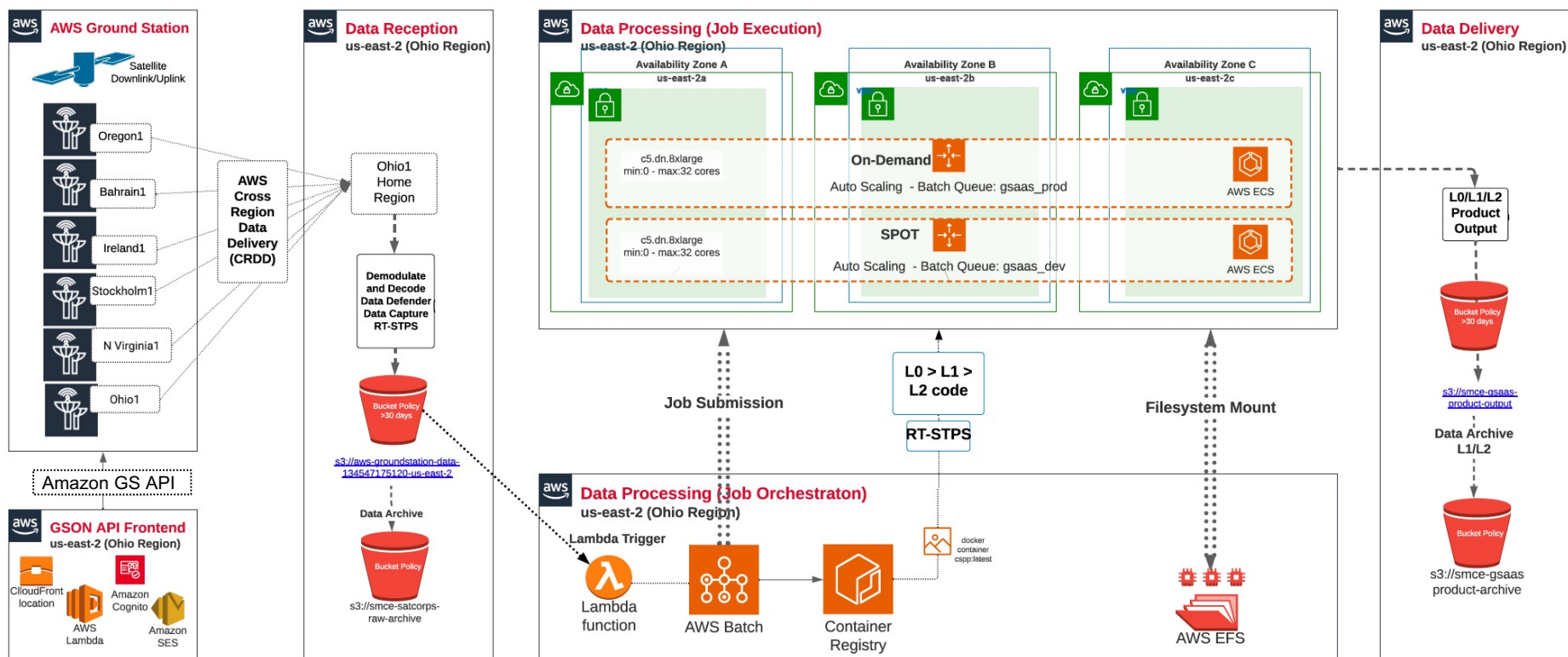
- AWS GSaaS
- GSON Services APIs (tasking, matching, job orchestration)
- Amazon Cloud and CloudWatch services
- Data Reception and Processing workflows





GSON System Architecture

Full System Architecture Diagram





GSON System Architecture

Conceptual Data Flow



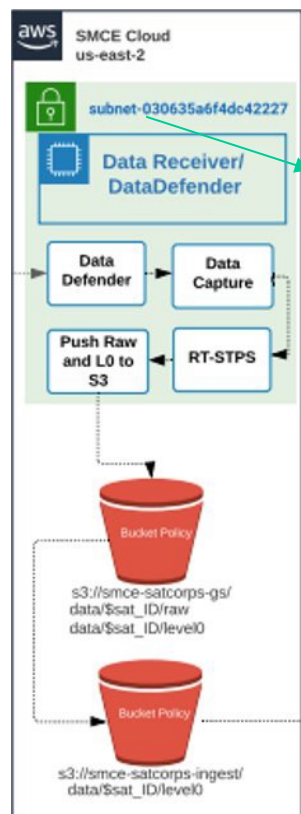
DB data captured by an AWS Ground Station near an area of interest

DB data transformation

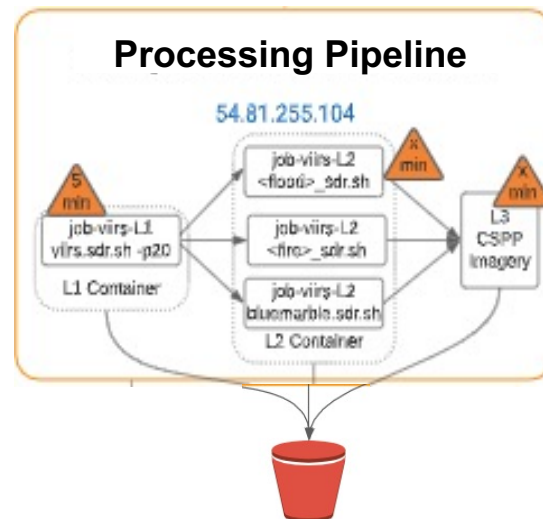
Phase 1 – Modulate/Decode
Sound wave → Raw → Level 0
(NASA DRL RT-STPS)

Phase 2 – Data Processing

- L1 – Science Data Records
- L2/L3 – Flood / Fire products (CSPP)



As science products become available, Notification message is sent to NOS-T and the product files are made available on AWS S3

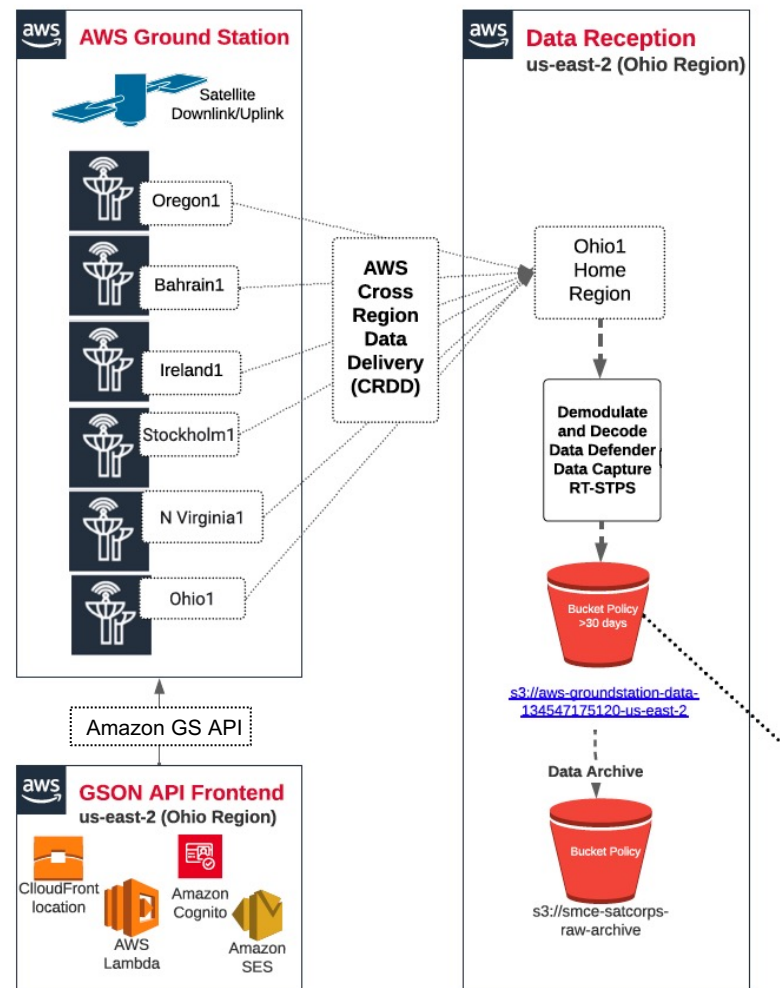
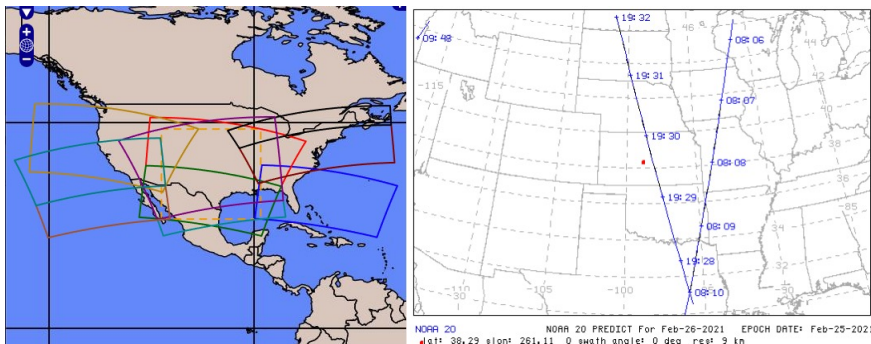




GSON System Architecture

Data Reception – Phase 1 Sound Wave to L0

1. Determine satellite overpass over location of interest
2. Reserve satellite contact
3. When satellite is within view, VPC instance receiver spins up to captures the DB Data
4. The Ground Station sends the sound file to the Receiver instance using Amazon high-speed Cross Region Data Delivery (CRDD)
5. Data gets demodulated and decoded through Data Defender and Data Capture and transformed to Level 0 using NASA DRL RT-STPS
6. Level 0 files are transferred to AWS S3 bucket for pickup and trigger further processing

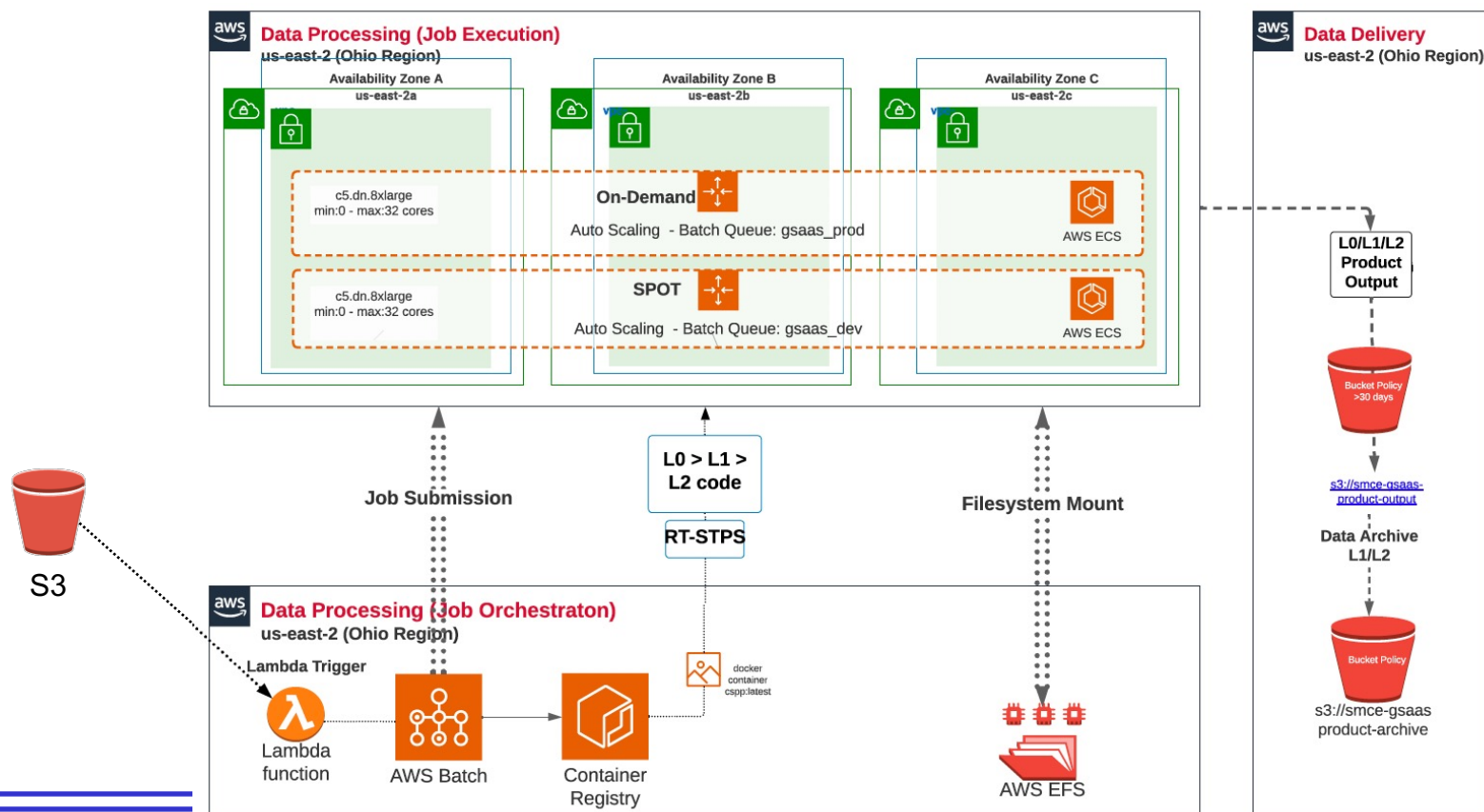




GSON System Architecture

Data Processing – Phase 2 L0 to L1 SDR to L2

1. L0 files in S3 triggers AWS Lambda, AWS Batch job process L0 files into L1 using Univ Wisconsin's CSPP SDR and sent to back to S3 bucket
2. L1 in S3 triggers Lambda and Batch job processing to invoke CSPP Science Data Product algorithms containers pipeline to generate L2/L3 products
3. Data products sent to S3 for distribution and Notification is sent apps/users/NOS-T node

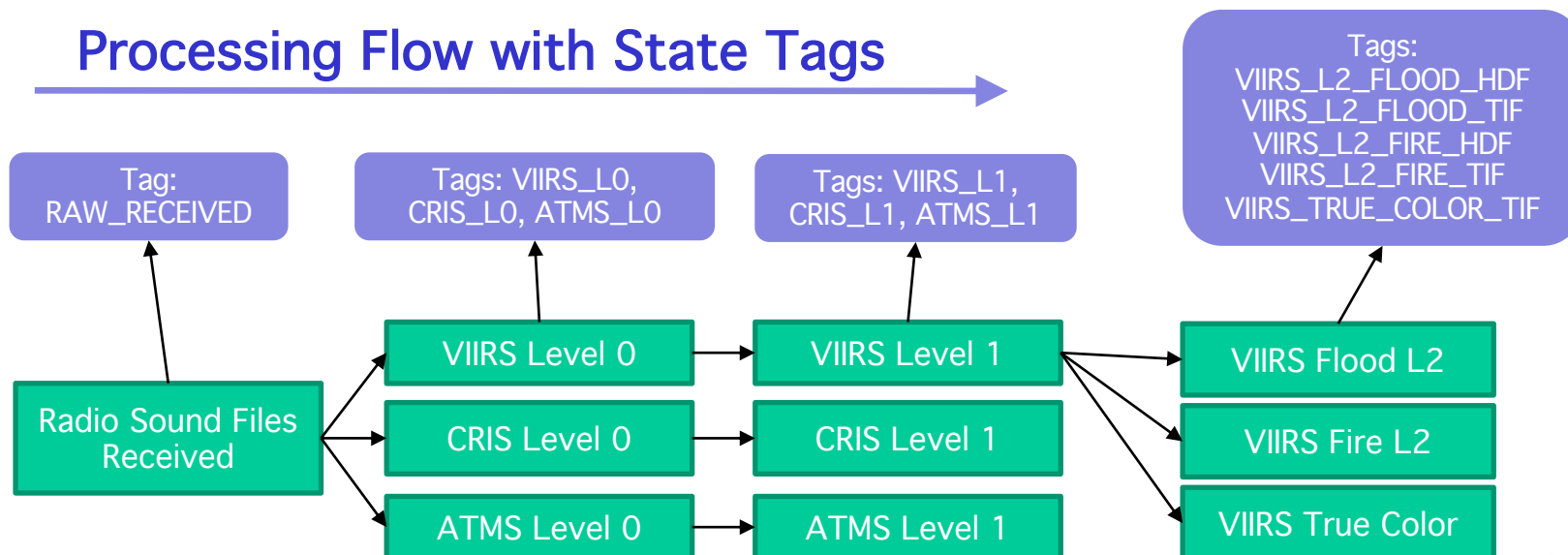




GSON System Architecture

- Allows for interoperability for end users to implement workflow
- Designed for efficient high-speed processing
- Utilize scalable multicore instances to Parallel process workflows
- Allows end users to easily attach custom processing, notification or scripting directly into the system
- Extendible to allow generation of more science products, alerts, or follow-on processing using “state tags”

Processing Flow with State Tags





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Direct Broadcast Products

NRT DB products derived from publicly available algorithms from NOAA and Univ Wisconsin CSPP:

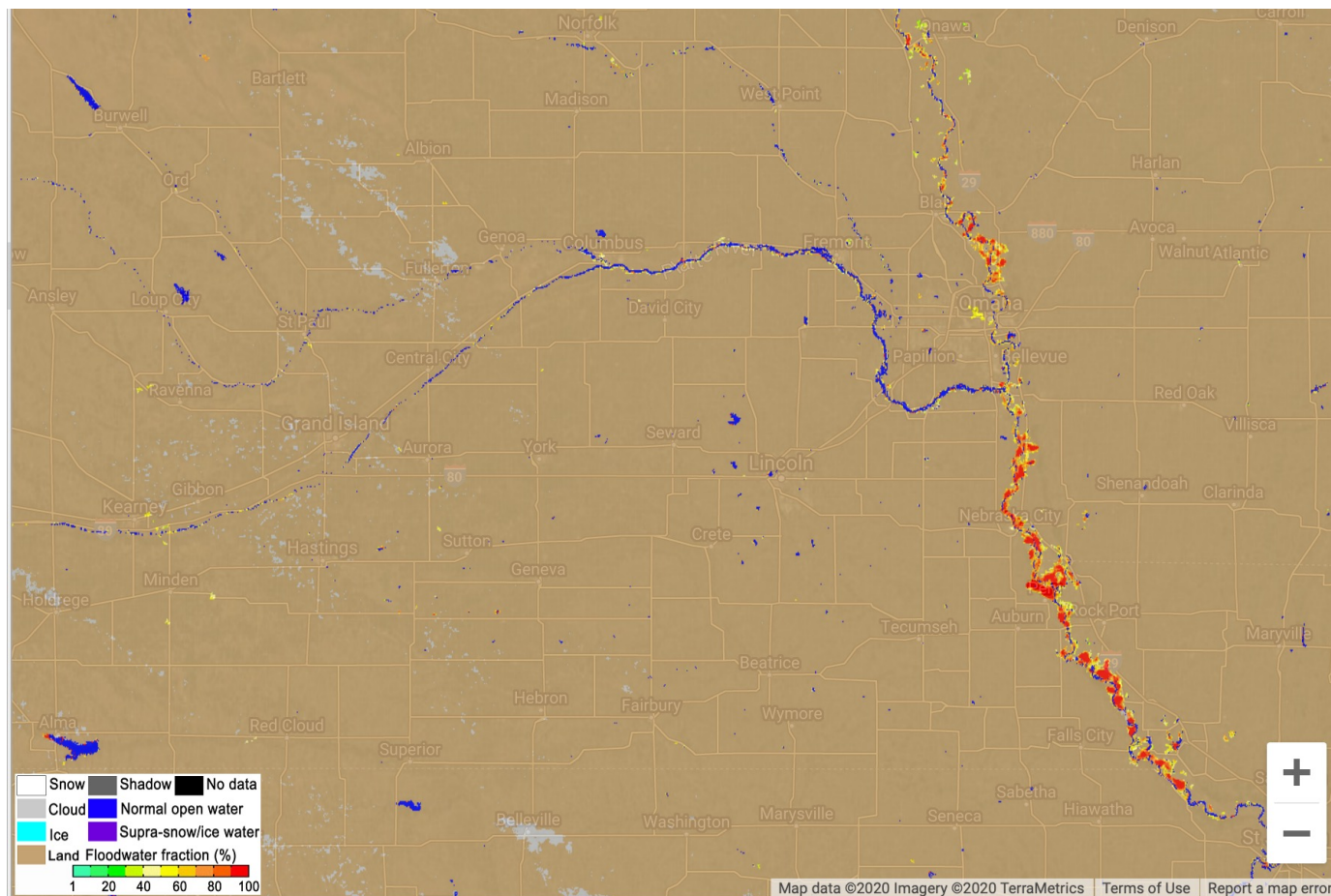
- NPP & NOAA-20 VIIRS Flood Detection (GeoTIFF)
 - 375m Floodwater Fraction (0-100%)
- NPP and N20 VIIRS Active Fire products (GeoTIFF and ASCII text)
 - 375m and 750m fire masks (radiative power and confidence)
- Clouds from AVHRR Extended (CLAVR-x) Retrieval
 - Cloud Retrievals such as cloud top/phase/optical properties
- Hyper-Spectral Enterprise Algorithm Package (HEAP) Atmospheric profiles of temperature, moisture, trace gases and radiances

GSON Framework allows for easy integration/inclusion of other processing pipeline via Docker Containers. Future plan to include CERES VIIRS/MODIS cloud properties retrievals.



Direct Broadcast Products

NPP & N20 VIIRS Flood Detection Map 375m resolution
(Acquired and processed on GSON System using Amazon GS)

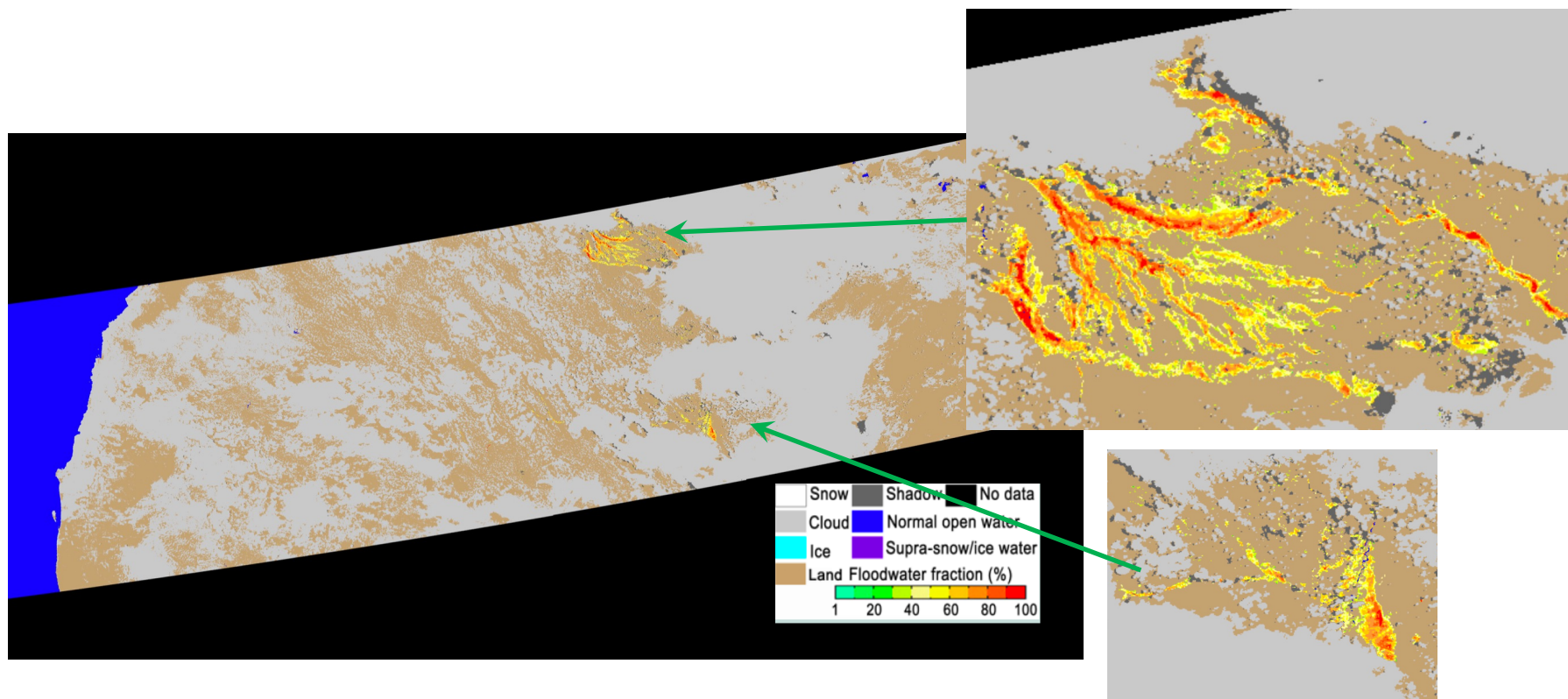


Level 1 → 2 Flooding processing time ~10-12min



Direct Broadcast Products

NPP VIIRS Floodwaters over South Africa acquired from GSON System using NOAA CLASS data on Jan 30, 2021

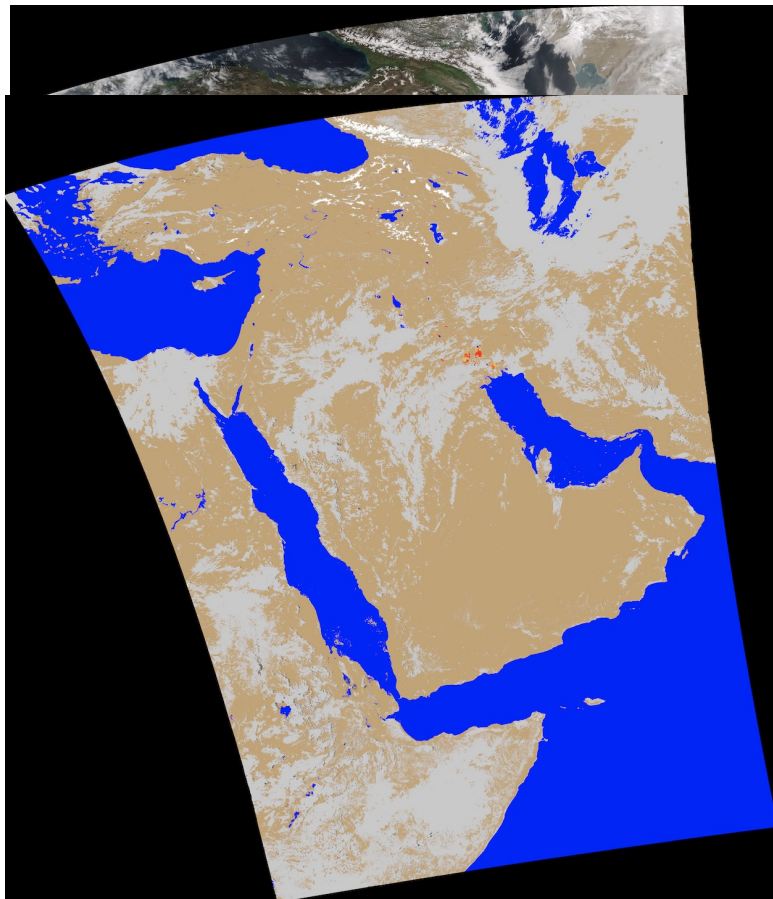




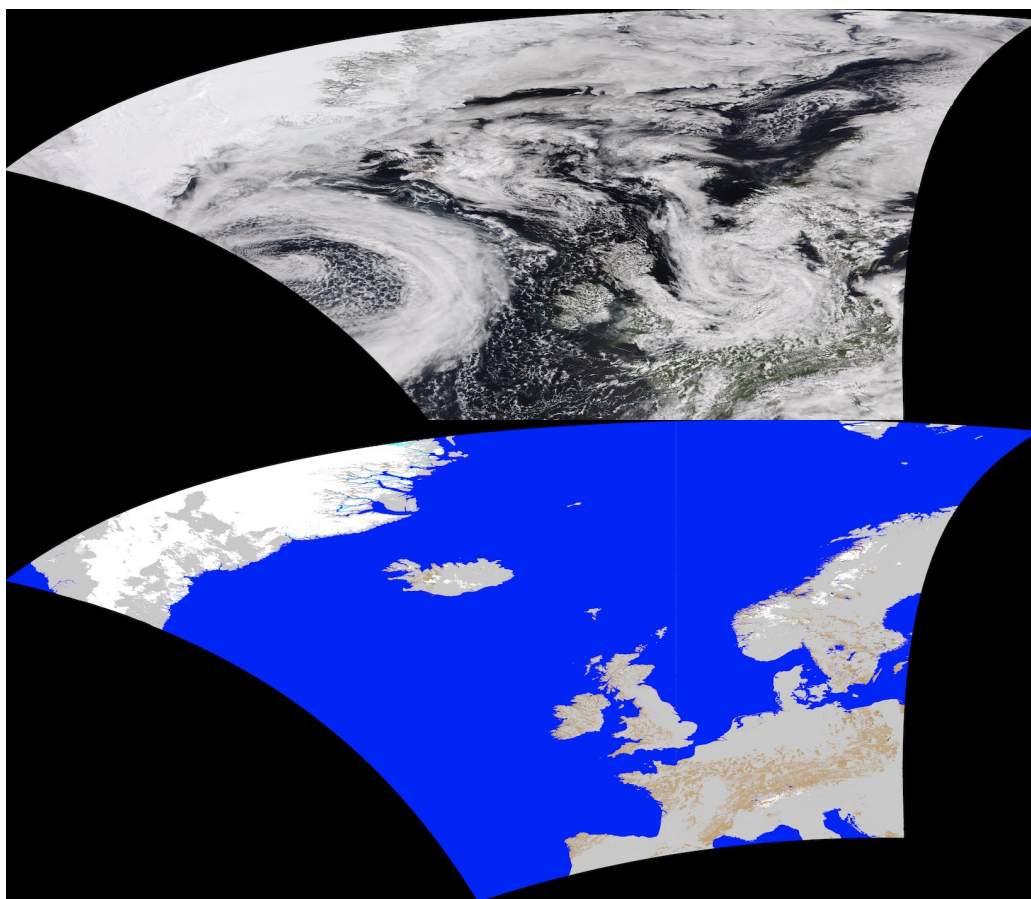
Direct Broadcast Products

NPP and NOAA-20 VIIRS Floodwaters over acquired from GSON System

NPP May 23, 2021 Bahrain GS



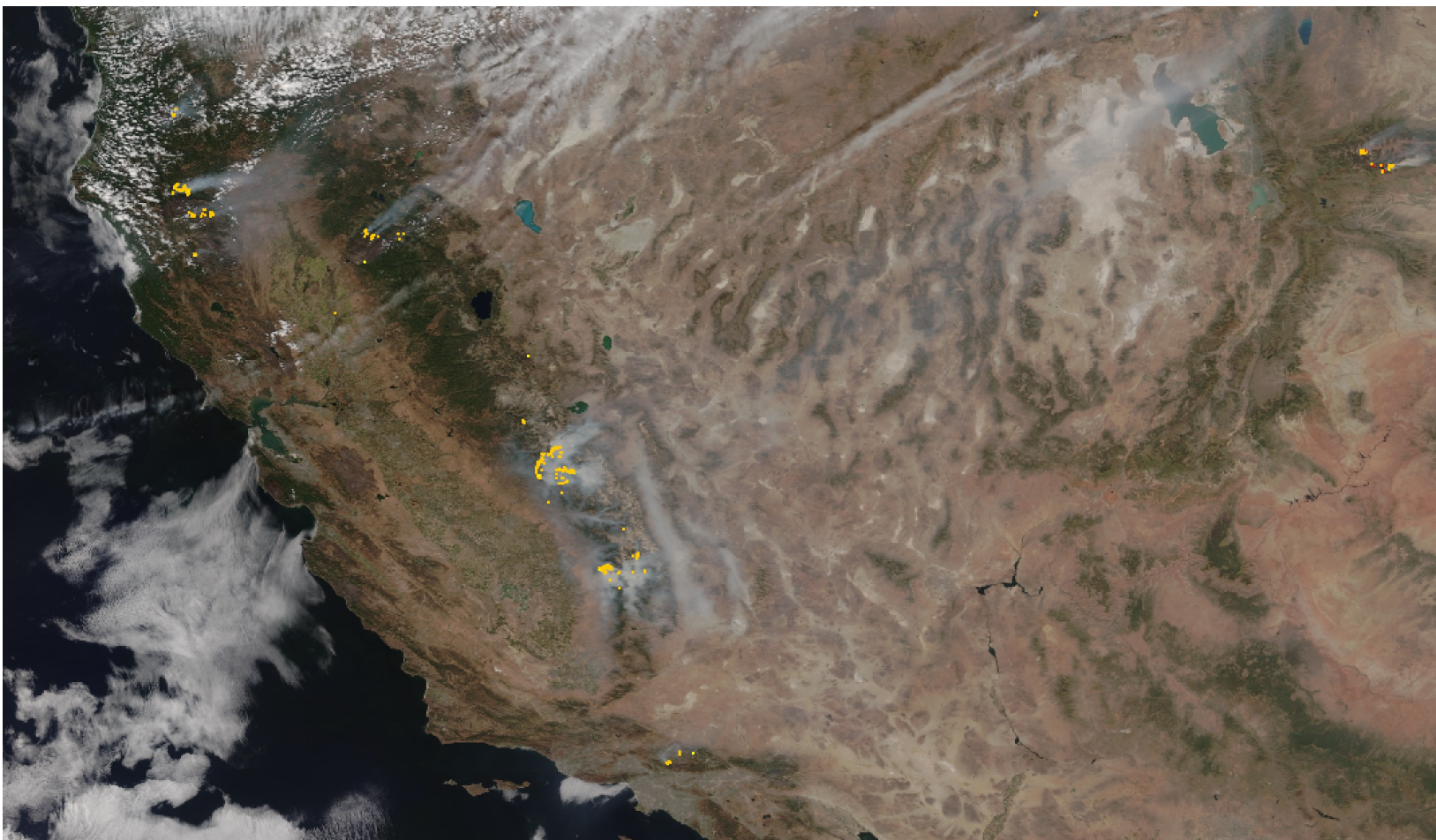
NOAA-20 May 18, 2021, Stockholm GS





Direct Broadcast Products

JPSS-1 VIIRS Fire Burn Map over California on Sept 24, 2020
(Acquired and processed on GSON System using Amazon GS)



Level 1 → 2 Fire processing time 3-4 mins



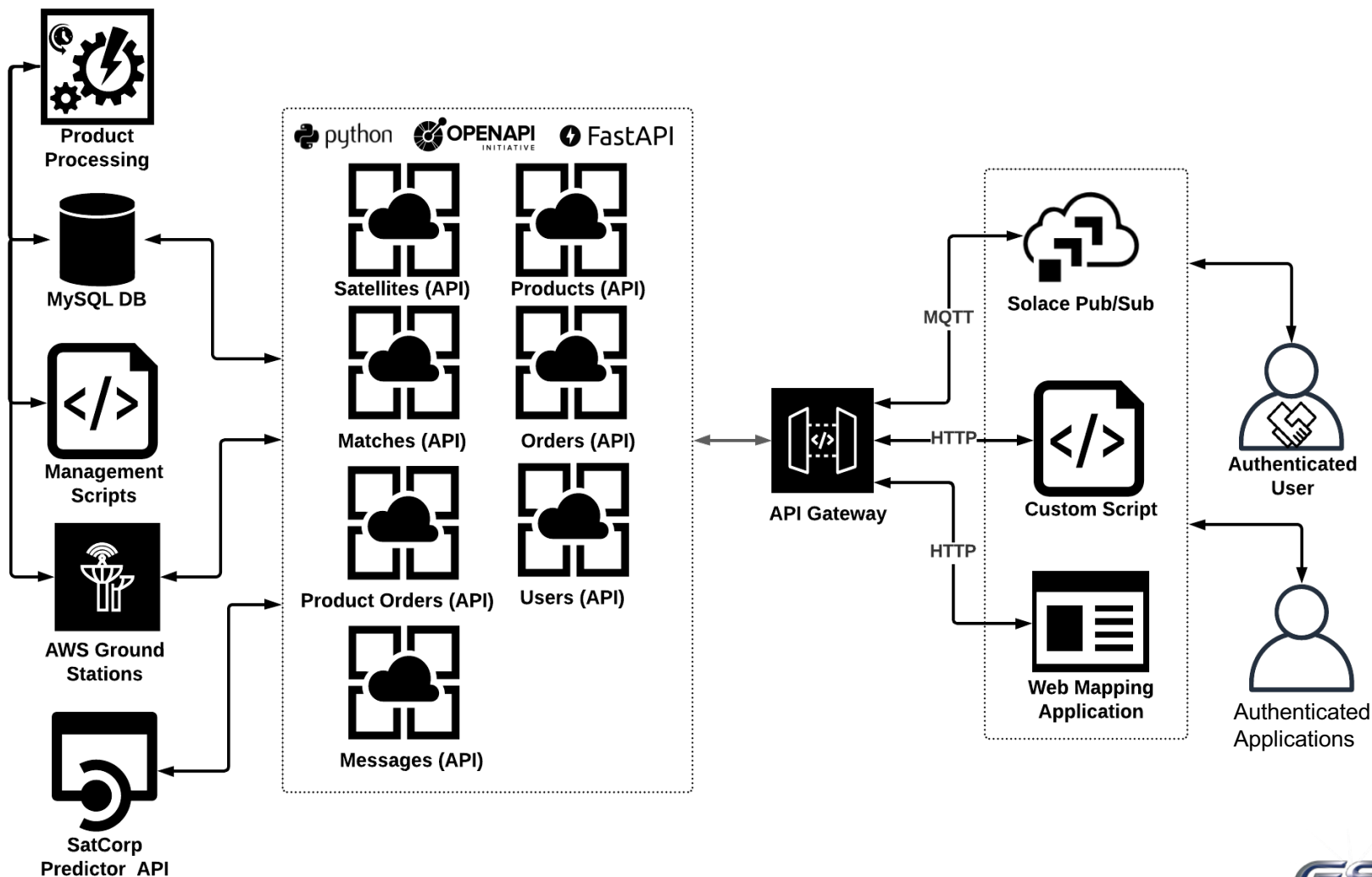
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GSON Service Layer Architecture

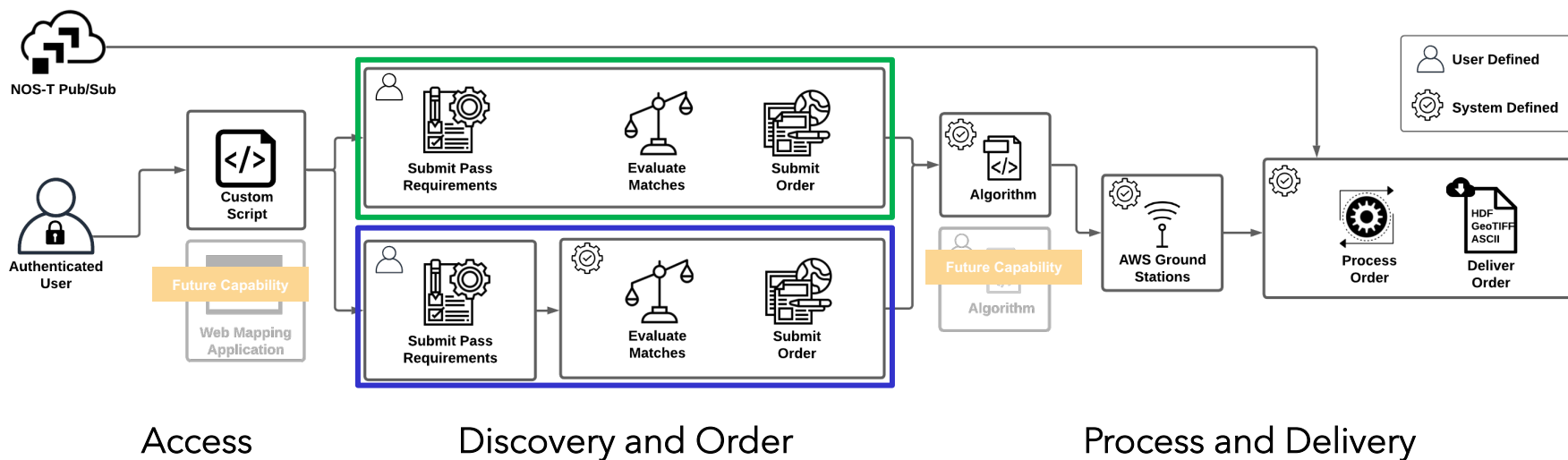
GSON API Service Architecture





GSON Service Layer Architecture

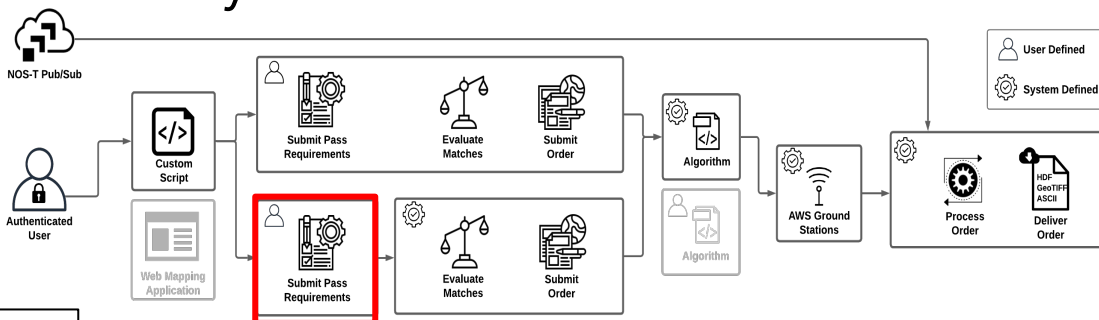
User Evaluated and System Evaluated Workflows





GSON Service Layer Architecture

System Evaluated Workflows



Submit Pass Reqs.

Orders	
POST	/gson/api/v1/orders/manual Submit a User-Defined order
POST	/gson/api/v1/orders/auto Submit an Auto-Defined order
Parameters	
No parameters	
Request body required	
<pre>{ "order": true, "latitude": 41.127289, "longitude": -95.917168, "satellite_name": ["JPSS1", "SNPP"], "instrument_name": "VIIRS", "product_package": "FLOOD", "days": 2 }</pre>	

```
{
  "order": true,
  "latitude": 41.127289,
  "longitude": -95.917168,
  "satellite name": ["JPSS1", "SNPP"],
  "instrument name": "VIIRS",
  "product_package": "FLOOD",
  "days": 2
}
```

User Submits Order with
Pass Requirements

Ability to submit:

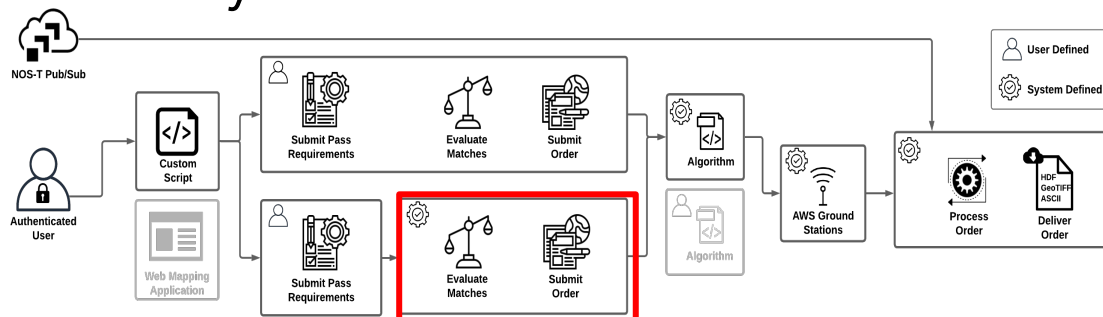
1. Multiple Satellites
2. Request Product Package instead of individual products



GSON Service Layer Architecture

System Evaluated Workflows

Execute and Order



Match UUID	Status	Ground Station	Start	End	Latitude	Longitude	Satellite	Instrument	Sat Elevation	VZA	SZA	Distance to Site
87e31f60ad1611eba94f120ed256a481	Expired	Ohio 1	2021-05-05T07:35:19	2021-05-05T07:47:29	41.1273	-95.9172	SNPP	VIIRS	41.32	48.68	119.69	786.2
87e3ec88ad1611eba94f120ed256a481	Expired	Ohio 1	2021-05-05T09:17:09	2021-05-05T09:22:10	41.1273	-95.9172	SNPP	VIIRS	26.34	63.66	108.99	1251.22
bc459908bfb411eb80ff120ed256a481	Available	Ohio 1	2021-05-28T19:19:44	2021-05-28T19:29:14	41.1273	-95.9172	JPSS1	VIIRS	79.8	10.2	23.55	132.49
bc466d74bfb411eb80ff120ed256a481	Available	Ohio 1	2021-05-29T07:36:32	2021-05-29T07:47:04	41.1273	-95.9172	JPSS1	VIIRS	42.49	47.51	114.58	757.95
bc46fb9abfb411eb80ff120ed256a481	Available	Ohio 1	2021-05-29T09:18:50	2021-05-29T09:24:05	41.1273	-95.9172	JPSS1	VIIRS	25.69	64.31	104.51	1277.28
bf220044bfb411eb80ff120ed256a481	Available	Ohio 1	2021-05-28T20:12:19	2021-05-28T20:16:23	41.1273	-95.9172	SNPP	VIIRS	28.54	61.46	30.68	1167.25
bf228baebfb411eb80ff120ed256a481	Available	Ohio 1	2021-05-29T08:26:02	2021-05-29T08:34:55	41.1273	-95.9172	SNPP	VIIRS	70.38	19.62	110.38	261.12

System evaluates matches and orders on behalf of user



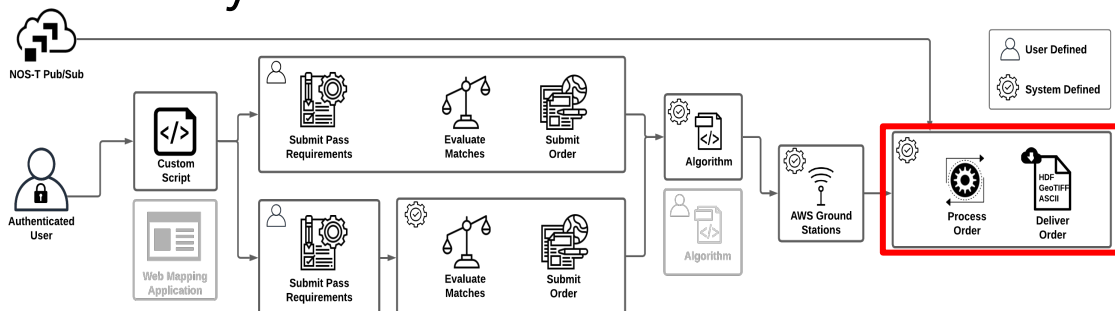
GSON Service Layer Architecture

Track Order

```
Code    Details
200      Response body
{
  "order_uid": "bf2b7de0bf411eb80ff120ed256a481",
  "order_status": "SUBMITTED",
  "contacts": {
    "satellite_name": "JPSS1",
    "ground_station_start": "2021-05-28T19:19:44",
    "ground_station_end": "2021-05-28T19:29:14",
    "ground_station": "Ohio 1",
    "contact_id": "0be72e21-b7c8-4061-a772-1f1d7269790c",
    "contact_status": "SCHEDULED"
  },
  "matches": {
    "match_uid": "bc459908bf411eb80ff120ed256a481",
    "distance_units": "METERS",
    "satellite_name": "JPSS1",
    "instrument_name": "VIIRS",
    "satellite_azimuth": "256.46",
    "satellite_elevation": "79.8",
    "viewing_zenith": "10.2",
    "solar_zenith": "23.55",
    "relative_azimuth": "36.88",
    "scattering_angle": "163.5",
    "glint_probability": "16.29",
    "satellite_heading": "345.55",
    "satellite_direction": "ASCENDING",
    "distance_to_site": "132.49"
  },
  "products": [
    {
      "product_order_uid": "bf2da34bf411eb80ff120ed256a4",
      "product_status": "PENDING",
      "product_id": "JPSS1_VIIRS_L2_FLOOD_GEO TIFF",
      "message_level": "FINE",
      "notify_method": "EMAIL"
    },
    {
      "product_order_uid": "bf2f9740bf411eb80ff120ed256a4",
      "product_status": "PENDING",
      "product_id": "JPSS1_VIIRS_L2_FLOOD_HDF",
      "message_level": "FINE",
      "notify_method": "EMAIL"
    },
    {
      "product_order_uid": "bf31215abf411eb80ff120ed256a4",
      "product_status": "PENDING",
      "product_id": "JPSS1_VIIRS_L3_FLOOD_GEO TIFF",
      "message_level": "FINE",
      "notify_method": "EMAIL"
    },
    {
      "product_order_uid": "bf32da36bf411eb80ff120ed256a4",
      "product_status": "PENDING",
      "product_id": "JPSS1_VIIRS_L3_FLOOD_HDF",
      "message_level": "FINE",
      "notify_method": "EMAIL"
    }
  ]
}

Response headers
access-control-allow-credentials: *
access-control-allow-origin: *
api-version: 1.0.0
content-language: en-US
content-length: 1422
content-type: application/json
date: Fri, 28 May 2021 13:00:47 GMT
server: uwicorn
x-process-time: 0:00:10.233862
```

System Evaluated Workflows



[EXTERNAL] GSON - Order Submitted

o GSON <no-reply@satcorps-larc.com>
To: o Barnett, Audy Jason (LARC-E301)[BOOZ ALLEN HAMILTON]

Order Information

There is an update to your order. Please see your order details below.

Updates
ORDER SUBMITTED

User: ajbarnett

Date: 05/28/2021, 13:01:02

Order UID: bf2b7de0bf411eb80ff120ed256a481

Order Status: SUBMITTED

Contact Information:

Contact Status	Satellite	Start (UTC)	End (UTC)
SCHEDULED	JPSS1	05/28/2021, 19:19:44	05/28/2021, 19:29:14

Product Information:

Product Status	Product UID	Product ID	Message Level	Notify Method	
PENDING	bf2da34bf411eb80ff120ed256a4	JPSS1_VIIRS_L2	FLOOD_GEO TIFF	FINE	EMAIL
PENDING	bf2f9740bf411eb80ff120ed256a4	JPSS1_VIIRS_L2	FLOOD_HDF	FINE	EMAIL
PENDING	bf31215abf411eb80ff120ed256a4	JPSS1_VIIRS_L3	FLOOD_GEO TIFF	FINE	EMAIL
PENDING	bf32da36bf411eb80ff120ed256a4	JPSS1_VIIRS_L3	FLOOD_HDF	FINE	EMAIL

[EXTERNAL] GSON - Order Updated

o GSON <no-reply@satcorps-larc.com>
To: o Barnett, Audy Jason (LARC-E301)[BOOZ ALLEN HAMILTON]

Order Information

There is an update to your order. Please see your order details below.

Updates
CONTACT UPDATED

User: ajbarnett

Date: 05/28/2021, 12:42:02

Order UID: b9e31b02bfb11eb9e74120ed256a481

Order Status: SUBMITTED

Contact Information:

Contact Status	Satellite	Start (UTC)	End (UTC)
SCHEDULED	JPSS1	05/28/2021, 19:19:44	05/28/2021, 19:29:14

Product Information:

Product Status	Product UID	Product ID	Message Level	Notify Method
PENDING	b9e31b02bfb11eb9e74120ed256a4	JPSS1_VIIRS_L2_FLOOD_GEO TIFF	FINE	EMAIL
PENDING	b9e7c2cebfb11eb9e74120ed256a4	JPSS1_VIIRS_L2_FIRE_NC	FINE	EMAIL

User receives Order Information Response and notified of Order Status during Processing



Summary

- Designed and deployed GSON system on AWS to receive and process Direct Broadcast data from Amazon Ground Stations to support NOS-T Demo
- Captured DB data from AQUA, NOAA-20, and NPP (MODIS/VIIRS)
- Developed data processing workflow to automatically process Level 0 -> 1 -> 2/3
- Able to process low latency VIIRS Active Fire and VIIRS Floodwater products using Univ Wisc CSPP science algorithms
- Improved workflow and processing speed to delivery products in under 25mins
- GSON Framework is interoperable and extendable to accommodate additional satellites, GSaaS, processing workflows, and science algorithms
- System well suited for ad-hoc use. Routine semi-operational use over large domains would require Interagency cost sharing support to make low latency DB available to benefit many projects



Future Plans

- Continue to build out GSON service API to allow apps/users/NOS-T nodes to schedule and reserve DB data and products
- Participate in NOS-T live Flood demo
 - Provide low latency VIIRS floodwater
 - Enable NWIS Flood Gauges to trigger low latency VIIRS DB request
- Prepare GSON node for standby to support future NOS-Live demonstrations
 - NPP and NOAA-20 VIIRS, AQUA/TERRA MODIS, VIIRS Floodwaters or Active Fires, or any other satellite products
- Possible Collaboration with:
 - GMU Flood group: TERRA MODIS Floodwater
 - NASA Disasters: perform short term VIIRS Active Fires demonstration
 - Jim Carr and Jaime Daniels (NOAA/STAR): Stereo 3D-Winds demo
 - Paul Stackhouse (NASA LaRC): VIIRS Clouds Products for Power and Solar communities